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THE EFFECT OF GEOMETRY ON SYMBOLOGY RECOGNITION

A Thesis

by

JAMES ANDRUS BOYLESS

Submitted to the Graduate College of
Texas A&M University
in partial fulfillment of the requirement for the degree of
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May 1979

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THE EFFECT OF GEOMETRY

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A Thesis

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May 1979

ABSTRACT

The Effect of Geometry
On Symbology Recognition. (May 1979)

James Andrus Boyless, B.S., University of Arizona

Chairman of Advisory Committee: Dr. Richard D. Huchingson

The present study was conducted to investigate the effect of geometry on symbology recognition. Military situations require symbology sets that are consistent with the encoded information being presented in electronic display systems. Often, the mission requirements dictate the need for either shape coding methods or other methods to encode the information desired. The effects of geometry on symbology recognition have been previously studied, but continued research must be accomplished in order to establish a standardized symbology set for use in electronic display systems.

The major independent variable in the research study was the geometric shape of a particular symbol. The four symbols investigated were the polygon, diamond, square, and triangle..

The experimental task involved monitoring a simulated threat warning display while simultaneously performing a compensatory tracking task on an adjacent scope. Subjects were to distinguish between two types of displayed events, supercritical or critical, by means of response time keys

and were then to identify verbally the type of event, its direction, and its range from the center of the scope. The events were coded by the geometric shape.

It was found that mean detection time and mean performance scores were not generally affected by the type of geometry for the recognition task. However, significant difference was found between the square and polygon and the square and triangle for the critical event mean detection times.

The research study indicated that all four symbols could be used equally well for any standardized symbology set.

ACKNOWLEDGMENTS

I wish to express my thanks to Dr. Richard D. Huchingson for his assistance in formulating and advising the research study. I also wish to thank Dr. James K. Hennigan and Dr. William P. Fife for their support and constructive criticism of the proposal and project. I must also thank Messrs. John C. Polasek and Jesse Condray for their invaluable assistance and use of their microcomputer equipment for the research study. A special thanks to Mr. Polasek for his assistance in formulating the computer programs for the project. And to the ROTC students that served as subjects--thank you.

DEDICATION

This thesis is dedicated to my wife, Peggy, for her support and encouragement during this educational endeavor. And to our son, Michael Anthony, goes a special dedication for his love and joy given freely during our stay in College Station, Texas.

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INTRODUCTION

Background

The primary role of a military aircraft is to perform its designated mission, either in an attack or a defensive role. Often, the mission aircraft is a single-seat fighter aircraft, capable of airspeeds exceeding the speed of sound, or a close air support aircraft operating in the subsonic regime. These two aircraft have a vast array of sophisticated equipment that the pilot has at his command to carry out a mission.

The equipment, in turn, must respond in a manner that will enable the pilot to increase the probability of success of the mission. But, with the duties of piloting, navigating, monitoring of gauges, and so on the information that the equipment presents may often overload the pilot during the attack or evasive postures.

The most important piece of equipment during this phase of the mission is the Threat Warning Display System (TWDS). The loss of information due to ineffective symbology may deny the pilot successful completion of the mission.

Most threat warning display systems present information that gives the pilot input as to search, track, or launch of enemy aircraft or missiles. Such information is often depicted in an X-Y plane, such as range and azimuth

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The citations follow the style of the Human Factors Journal

or range and altitude (Kama, et al., 1973). Other methods to present pertinent information to the pilot, in a usable form, for prompt and efficient responses have been documented (Honigfeld, 1964; Semple, et al., 1971).

Many of these methods have been by means of symbolic representation to present additional information. Honigfeld (1964) states that the coding system should be such that "the radar operator must in the minimum time make effective and precise decisions," and also ideally, coding should convey the importance of its content. The best coding system is one that has a characteristic pictorial shape (Howard, 1963).

Research has been performed on coding systems that include brightness, flash rates, size, shape, orientation, color, number of dots, length of lines, etc. Van Cott and Kinkade (1972) have tabled these parameters of coding and have compared each with one another. They then recommend the maximum number of each.

Whatever the coding system used, the overriding factor is that it make information available immediately, reduce the operator memory load, free communication channels, and provide a better picture of the total situation (Honigfeld, 1964).

Problem

The many dimensions of coding have led to a great

number of systems, often unique to a particular military hardware system, which have resulted in decreased comprehension and perception time (Honigfeld, 1964). The pilot moving from one aircraft system to another may encounter a different coding system that decreases his ability to react and respond quickly.

Appealing to the manufacturers of threat warning display systems and specifically radars, Honigfeld (1964) suggested that a standardized method of coding be employed such that it would increase the efficiency of the operators while decreasing the number of unique coding methods. Another more recent report, The Joint Tactical Identification Display System Guide (Casella, et al., 1977), again addressed the question of standardization and they made specific recommendations as to number, size, shape, orientation, etc. that will be the most effective for mission requirements.

Hypotheses

The present study compared four symbology sets in a laboratory experiment to assess the effects of geometry on symbology recognition. It presented geometric shape variations of each symbology set that included the common shapes of the polygon, diamond, square, and triangle. It was predicted that the diamond would be found to be significantly different from the other three shapes investigated

due to the brightness of the symbol and would be followed by the square, polygon, and triangle. It was also hypothesized that response times for detection, recognition responses, and tracking would be significantly different for each symbology set. It was predicted also that the symbolic set which ranked highest on recognition performance mean scores would also have better performance on a simultaneous tracking task. The simpler recognition task would allow more time for tracking.

LITERATURE REVIEW

In the particular experimental research it was necessary to understand the man-machine system (MMS) relationships between the man and the machine. The very model of the MMS in a closed loop situation, dictates a systematic approach to each element be used. Figure 1 shows the interrelational aspects of the MMS.

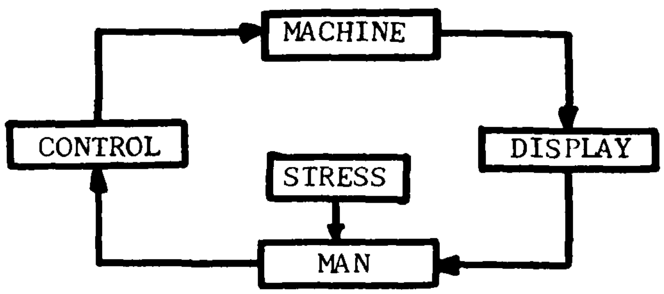

Figure 1. The MMS in a Closed Loop.

In the experimental research study, the MMS was limited to the display and man. The display aspect of the MMS was further delineated to represent an electronic display system that was capable of generating encoded symbolic information. Studies conducted previously have shown that visual coding of information has aided the pilot (man) in the performance of his mission.

Ketchel and Jenney (1968) stated that the purpose of a display system is to present information to the user. The amount of information to be presented must be considered in terms of comprehension, display access time, and human perception. How the information is presented has not been standardized throughout the military services (Honigfeld, 1964). Various authors have reported that encoded information has the best opportunity to be processed by the user in a timely and accurate manner (Howard, 1963; Honigfeld, 1964). Howard (1963) reported that encoded information that best characterized the original information would be the easiest to learn. For display purposes, one important aspect of any coding dimension is the number of discrete, absolutely identifiable values it provides. Generally, encoding information for displays has been through visual coding.

But, processing the encoding information is also a function of the man in the system. His capability as an information processing system is dependent on the tasks of

the pilot (man) (Honigfeld, 1964). The demands of the system will determine the attention given to the visual display and the information presented. Sherr (1970) also states that the data rate of the system must be in the range of 50-100 bits/second, that is, presentation of the data. The vision sensory channel of man has the capability of processing 1.60 to 3.25 bits of information according to Van Cott and Kinkade (1972).

Both visual coding and the information processing capability of man must be reviewed as a basis for the present research study.

Visual Coding

It has been documented that there are unlimited methods of coding information (Honigfeld, 1964; Semple et al., 1971; Van Cott and Kinkade, 1972; and Kama et al., 1973). Visual coding of information is one method used to present information to a pilot in modern aircraft (Semple, 1971).

Under this method, there are still major sub-divisions of the coding scheme. Sub-divisions of color, magnitude, inclination, and shape have been shown to be good ways of presenting information. Van Cott (1972) has documented comparisions of these sub-divisions and their advantages and disadvantages.

Color Coding. Honigfeld (1964) reported various

researchers have performed studies using color (Erikson, 1952; Cohen and Senders, 1952; and Muller, 1955). Among these researchers a consensus was reached that indicated the use of color was an attractive coding method. It readily commands attention and stands out in experience. Quick responses and clear cues to discrimination of complex patterns have been reported (Cohen, 1952; Erikson, 1952). Both colored lights and pigments have been used to encode information. Colored lights are the easiest to use but pigments provide more coding steps (Semple, 1971). Chapanis and Halsey (1956) and Bishop and Crook (1960), reported by Van Cott (1972), concluded that color coding is limited by luminance, visual angle, and even the color used. Van Cott (1972) further reported another restriction of color coding. If large numbers of colors are used then continued training must be maintained to make accurate identification.

<u>Magnitude coding</u>. This type of coding can be used to encode information through the use of area or visual number coding. Area, as a coding method, is limited in scope. If more than five areas for codes are used then their utility diminish (Baker and Greuther, 1954 and cited in Van Cott, 1972). Van Cott (1972) recommends that a constant ratio pattern be used if this coding method is utilized. Honigfeld (1964) recommends that the ratio be in the range of 0.05 to 0.30 inch diameters (0.13-0.76 cm).

The use of visual numbering systems for coding has

been reported by Honigfeld (1964). In the report, it cited that both Oberly (1924) and Kaufman (1949) found errors were neglible for identification of signals coded by five dots or less but above six dots errors rose rapidly. Kaufman (1949) also reported the subject's confidence in their estimates was maximum up to six dots but dropped rapidly and leveled off.

Inclination coding. Honigfeld (1964), Van Cott (1972), as well as others have reported that inclination coding can be used for accurate information processing. The coding method consists of a line extending from a central hub. Information is contained in discrete steps of inclination. The positions of 0, 90, 180, and 270 degrees are quickly and accurately identified under all conditions. Muller (1945), as reported by Honigfeld (1964), presented data that 90 percent of the population should be able to identify 24 inclination code symbols with almost no error after two or three hours of training. But he also stated that no random variation of inclination must be present on the display.

Honigfeld (1964) concluded that the value of angular orientation to encode target course information is dependent upon target-course accuracy requirements.

Shape coding. Of all the dimensions used for coding, shape is perhaps the most widely used for display systems (Ketchel and Jenney, 1968). Human sensitivity, as reported by Van Cott (1972), is very high in the ability to

discriminate shapes. The number of steps or categories of this method is relatively large thus allowing large quantities of information to be presented to the user. Sleight (1952), cited in Honigfeld (1964), found fifteen highly discriminable shapes. Shape coding also permits transformation of real world objects for easiest presentation on display system screens, as well as permitting interpretation of real world qualities that are not three dimensional (Ketchel, 1968; Semple, 1971).

Encoding quantitive information that is readily adaptable to shape coding has been reported by Ketchel (1968). The results of this research have been important since it indicated that large "alphabets" of symbols can be utilized for encoding information.

There are generally two types of shape coding in use today. Pictorial shape coding is the method of using the associated characteristic shape of the object to be encoded. Both military and aircraft symbols are representative of this type of coding. Van Cott (1972) stated that pictorial shape coding depicts the real world object they represent and are easily learned, remembered, and used.

Geometric shape coding is the second type of method used to encode information. Howard (1963) reports that arbitrary shapes provide an efficient means of presenting complex thoughts, objects, or events. Honigfeld (1964) stated that geometric shapes were emphasized by Gestalt

theorists as being excellent means of information communication. Calfee (1975) states that shape patterns are dominant and unique characteristics of human perception. With this concept in mind, Honigfeld (1964) cited a study by Hochberg et al. (1948) in which the circle, because of its simplicity, symmetry, and regularity was found to be the most perceptible. It was followed in ranking by the square and cross. Honigfeld (1964) was critical of the finding because of the few forms used in the experiment.

Further studies dealing with the ability to discriminate shapes and their compatibility with other shapes have been reported by Honigfeld (1964), Ketchel (1968), and Semple (1971) among others. These reported studies include researchers as Caperson (1950), Sleight (1952), Deese (1956), and Bowen (1959).

Caperson (1950) studied the discrimination threshholds of six geometric forms and tried to relate three quantitative aspects to their relative discriminability. He used maximum dimension, area, and perimeter and found that regardless of the measure used the triangle, cross, and rectangle were consistently superior to the star, diamond, and ellipse unless the ellipse became a circle. It then ranked third. Finally, increasing any measure also increased the probability of detection and recognition.

Sleight (1952) had subjects sort out 126 items, ix samples of 21 geometric forms. His results showed

that the swastika, circle, crescent, airplane, cross, and star were superior to rectangular and triangular shapes.

Semple (1971) cited a study by Deese (1956) that found even one geometric form in a symbology set was consistently and accurately reported regardless of complexity of the shape.

Bowen et al. (1959) conducted a study to determine the optimum symbols for radar displays. Of the twenty geometric forms tested it was reported that the best combinations of five symbols each were 1) rectangle, circle, zig-zag Z, cross, and semicircle or 2) cross, semicircle, ellipse, triangle, and square.

These studies led Honigfeld (1964) to make specific recommendations for shape coding of information for radar displays. These can be summarized in the following manner:

1. If shapes are to be used, then their number should be limited to six, especially if adverse conditions are to be encountered.

2. Variations of a single geometric form should be avoided.

3. Unique symbols are good in specific situations.

4. The circle, rectangle, cross, and triangle are highly discriminable.

5. Squares, polygons, and ellipses should be avoided.

6. Symbols should be compatible with viewing distances, and not less than 12 minutes of arc at 28 inches (71 cm).

7. Symbol meanings should be compatible with conventional meanings.

In addition to these recommendations, Sherr (1970) also stated that the significance of the visual coding method lies in the operational analysis of task requirements.

Pilot Performance

The performance of the pilot (man) in the MMS is highly dependent on many variables. These variables include the interactions of the machine, display, controls, and stress.

Man, in the MMS, can be generalized as an information processing system. Gillies (1965) and Van Cott (1972) both use this model to determine the requirements of the individual for processing information.

Gillies (1965) reports that the information presented to the individual (man or pilot) is categorized into two classes, either status or command information.

Status information relates to the current state of the aircraft while command information relates to what the state of the aircraft should be.

Regardless of the task information to be processed by the pilot, Gillies (1965) reports that he either excels or is limited by his own information processing system.

Gillies (1965) and others state that man in the MMS excels in his ability to judge the importance, organize by experience, and then logically approach information to solve a problem.

Two of his limitations lie in the areas of rapid calculation and performing boring or fatigue inducing tasks. But, he is further limited by information channel capacity, poor monitoring ability, built-in lags, and environmental stress (Gillies, 1965).

Limited Channel Capacity. The auditory, propioreceptors, and vision senses all provide inputs to the information processing system model of the pilot (Gillies, 1965).

Auditory information can be received by the pilot from communications with the ground, from the aircrew members, and even from the aircraft. The propioreceptors provide tactual cues through the "feel" of the aircraft.

Vision is the most used sense in the flight tasks of the pilot. The information received by this sensory channel can be either direct or indirect. Direct visual information is received from the external environment of the aircraft. Indirect information is received from the aircraft instruments and display systems. Both types of information require the pilot to discern the smallest detail at any viewing distance (Van Cott, 1972).

Overstimulation or understimulation of the visual sensory channel can cause either degradation or inaccurate reporting of received signals. Gillies (1965) cited a study by Fitts (1950) that reported eye movements increased as workload increased. Van Cott (1972) stated the

probability of detecting a change in a visual display is dependent on the characteristics of the target and more importantly, the pilot's visual capabilities.

Monitoring Ability. Gillies in 1965, reported that man's ability to monitor incoming information is heightened by greater inputs but that the reverse was also true. He further stated that as stimulation of the visual sensory channel decreases pilot performance will decrease. To reduce this occurrence, Gillies (1965) suggests that additional tasks be performed and thus reduce the ineff-iciency of performance.

Human Time Lags. McCormick (1970) reported that reaction time was dependent on the sensory channel used for transmission of the information. Generally, the reaction time of a subject, when presented a stimulus at random, was between one-third and one-fifth second (Gillies, 1965). McCormick cited the work of Damon et al. (1966) in which he reported that increasing the number of stimuli or number of tasks to perform will increase the time for response. Sherr (1970) also found that response was dependent on viewing distance, display element size, and visual acuity. The human lag time for response time has been proposed by Mitchel (1967) and reported by Sherr (1970). It is a mathematical formula that describes the human as a function of both operator transposition lag and short neuromuscular delay. The drawback of the model lies in its inability to

accurately describe both these terms.

Environmental Stress. Gillies in his A Textbook of Aviation Physiology (1965) reports that there is both physiological and psychological stress. He states that physiological stress can be stress induced by temperature while psychological stress may be fear that failure may decide the future. Gillies (1965) cites a study by Harris et al. (1956) that reported stress can be classified as either short-term or long-term dependent on the amount of time the subject is subjected to the stimulus.

Short-term stress, as defined by Harris (1956), is stress induced by the stimulus over a period of a few minutes to an hour. He defined long-term stress as a stimulus presented to a subject over a period of more than an hour and even months.

Harris (1956) further delineated short-term stress into five categories; failure, distraction, fear, physical discomfort, and speed and load stress. Of the five, only speed and load stress describe the stimulus in terms of its characteristics while the rest describe the effects of the stimulus on the subject.

Long term stress was subdivided by Harris (1956) into three categories; dangerous duty, confinement, and biological stress. The first two categories describe the characteristics of the stimulus while biological stress describes the effects of the stimulus on the subject.

Lazarus (1952) and reported in Gillies (1965) summarized failure stress as loss of efficiency in performance when the subject knows that failure is imminent.

Researchers of distraction stress were not in consensus but in general, reported that unfamiliar stimuli initially caused a degradation in performance.

Fear stress studies by Strongin (1941) and cited by Gillies (1965) showed that visual performance was reduced by the threat of an electrical shock. Gillies (1965) also cited studies by Combs and Taylor (1952) and Kohn (1954) that indicated that fear stress reduces efficiency.

Physical discomfort stress has been studied by Mackworth (1950) in which he used a hot environment. He found that hot environments reduced performance. He also studied the effects of a cold environment in 1951 and found that manual dexterity was affected first while mental abilities were affected less.

Speed and load stress has been noted to reduce performance if a number of tasks are required to be performed. McCormick (1970) cited the work of Conrad (1955) that defined both speed stress and load stress. Speed stress is essentially a reaction on the part of the subject working on a task that has the effect of worsening his performance beyond that expected. Load stress changes the nature of the task. As the number of signal sources (visual displays) increase, more time is required to make judgements

due to the greater scanning coverage needed.

Siegel and Wolf (1969) reported that mild load stress is similar to workload stress. When there is less than adequate time to complete a task these authors reported that the mild workload stress acted as an organizing agent for time expenditures.

This type of stress can be measured and classified. Siegel and Wolf (1969) divided workload stress into threea areas; no stress leading to no decrease in performance, mild stress that has a beneficial effect on performance, and high stress that decreases performance.

Of the long-term stress categories, only biological stress may be apparent in this research, even in the short amount of time expected for the experimental task. Gillies (1965) cited that Wilkinson (1956) found that even a loss of one night of sleep impaired both perceptual and psychomotor performance.

EXPERIMENTAL METHOD

Subjects

Twenty Air Force ROTC students participated as subjects. Each subject was tested for normal or corrected 20/20 vision with the Snellen eye chart. In the subject pool 15 were found to have normal 20/20 vision while five had corrected 20/20 vision.

The subjects were randomly assigned to a group of five subjects each. Each group was presented a specific order of symbology sets in order to counterbalance any presentation effects. The order of presentation is tabulated in Appendix A. The presentation scheme is a 4 X 4 Latin Square with each treatment appearing once and only once in each row and column.

The experimental method led to a one-way single factor design for analysis. Each subject provided twenty experimental measurements. These measurements included the primary areas of interest; detection times (8), recognition scores (8), and pilot rating (4).

During the experiment each subject was tested on each of the four symbology sets thus providing 400 experimental measurements.

Apparatus and Facility

The illumination, during the experiment, was darkened to simulate the low light conditions of a night or late

afternoon mission. Ambient lighting was approximately 0.1 fL.

The equipment for the experiment (Figure 2) included two microcomputers (Comodore PET 2001 Series) with attached video screens, one video monitor (Sony Model CVM-920U), one two-axis joystick (HUH Electronics), one group of three each standard telegraph keys, and one single impulse counter (Lafayette Instruments, Model 58022).

Each microcomputer was individually programmed for the experiment (see Appendix C). One program generated the symbology under test as well as the threat density scenario for the entire simulated flight mission.

A second program produced the tracking task and was the overall controller of flight mission duration or time for the experiment.

The microcomputer for the threat warning display system was further delineated on the screen by a four inch diameter range circle. The four inch circle was used to simulate the effective display area of a typical Cathode Ray Tube (CRT) found in aircraft threat warning display systems.

Only the conventional range presentation method was used throughout the experiment. This method of range presentation is based on concentric circles equidistant from the center of the screen.

The video monitor, used to present the tracking task, was placed above the recognition task microcomputer screen

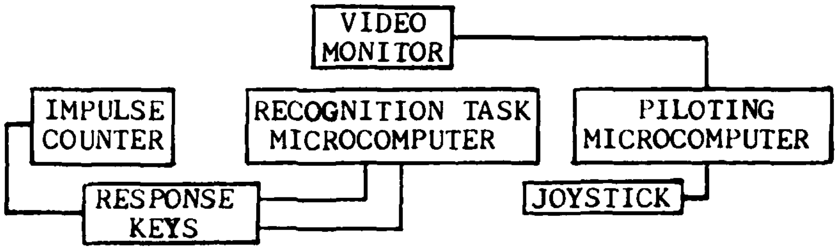

Figure 2. Schematic of experimental equipment design.

to simulate the approximate positions of the equipment in an aircraft cockpit.

Of the three response or telegraph keys, two were electrically connected to the recognition task microcomputer and the third key was connected to the single impulse counter. When tapped, the electrically connected keys stopped the timers within the recognition task microcomputer. Each response time was recorded for analysis.

One response key was always used for the supercritical events. The second response key was always designated as the key for the critical events while the third key was used by the subject to count the number of noncritical events.

The two-axis joystick was electrically connected to the tracking task microcomputer and provided digital feedback information for centering the aircraft symbol on the video monitor.

Procedure

Prior to starting the experiment, each subject underwent a short 10 minute training session. The subject was instructed (See Appendix A) on both the recognition and tracking tasks to be performed during the experiment. Emphasis on performing both tasks equally well was stressed but that the piloting of an aircraft is the primary role of the pilot and that this should command attention.

During the training session the subject was presented,

individually, the recognition and tracking tasks. He was exposed to the practice sequence of threat density scenarios for two periods of 100 seconds each. Accordingly, he also had two 100 second periods of tracking task practice.

The subject was instructed on how to respond to the threat warning display system when an event occurred. The symbology sets, the supercritical, critical, and the non-critical events were explained in detail. The practice period of 100 seconds was then administered to the subject. Again, the subject was instructed how to respond if any events occurred.

The subject had to respond when a supercritical, critical, or noncritical event appeared on the threat warning display system (TWDS). The procedure used was:

1. Hit the correct key
2. Verbally respond by
    a. State Priority
    b. Give Clock Direction
    c. Give Range

For Example: After hitting the correct key, the subject would respond by stating: "Supercritical, 3 o'clock, 15 miles." The subjects were also directed to respond by priority, that is, supercritical first, critical only after all supercritical events have been reported, and then the noncritical events. During the experiment there were 19 frames of events that the subject responded to.

These events were a mixture of supercritical, critical, and noncritical. They were randomly selected, that is, a random number of events was selected, then the events were placed randomly on the scope. All positions on the scope were equally likely to occur thus the events were scattered throughout the visual area.

The experimenter recorded each verbal response of the subject to each threat scenario with the aid of a checklist.

The practice period for the compensatory tracking task was then administered to the subject. The purpose of the joystick was explained and the subject was directed to center the aircraft symbol in the center of the video monitor screen.

After the recognition and compensatory tracking tasks were practiced the subject was then given both tasks simultaneously. He responded to the TWDS while he tracked the aircraft symbol.

Progressing to the actual experiment, the subject was again instructed how to proceed and how to respond to the TWDS. When the subject was ready, the experiment began.

Each data mission averaged 10 minutes in length and was designed to test the response time of the subject to a particular symbology set, determine accuracy in reporting, and performance in compensatory tracking.

Scoring

Scoring the performance of each subject was done in the following manner. Points were awarded for correct identification in three areas--symbol, clock direction, and range. The subject received three points for correct symbol identification, one point for clock direction, and one point for range. Only one-half point was awarded if the range report was within ± 5 miles. If the criteria of reporting a symbol was met, a maximum of five points was earned. If the criteria was not met, zero points were earned. If, in the course of reporting the symbol, an incorrect response key was activated the subject was penalized three points for each incorrect activation.

The maximum number of points that could be awarded for the recognition task was 235. The supercritical events could be awarded a maximum of 85 points while the critical events could be awarded a maximum of 150 points.

The compensatory tracking task was automatically scored by the piloting microcomputer. The maximum number of points for this task was 1000.

RESULTS AND DISCUSSION

There were three areas of interest in this experiment. One area, that of detection time, is depicted in Figures 3 and 4. The figures graphically present the mean detection times for all four symbology sets. The square had a slightly faster mean detection time for both the supercritical and critical events, 1.56 seconds. The triangle, diamond, and polygon followed in that order for the supercritical events, while the order for the critical events was the square followed by the diamond, polygon, and the triangle.

In the experiment, it was hypothesized that the diamond would be the symbol most readily detected for the supercritical events since it was "brighter" than any of the other symbols. This brightness was due to the reverse field diamond used for presentation on the Cathode Ray Tube (CRT). The reverse field effect is that effect that occurs when the entire symbol is filled in with raster lines. The brightness of the symbol is increased when compared with the other symbols of the experiment.

According to previous studies on discrimination of symbols (Bowen, 1959) it was further hypothesized that the order would follow square, polygon, and triangle.

For the critical events, it was again hypothesized that the diamond would be most easily detected according to the Bowen (1959) study, and followed by the square, polygon,

and the triangle. Figure 4 shows that, in this experiment, the square was detected slightly faster while the diamond was second. The polygon and triangle followed their respective positions in the hypothesis.

In order to evaluate the important aspects of shape coding associated with each symbology set, a statistical analysis of variance was performed on the detection times for all four symbology sets. Tables 1 and 2 summarize the analysis.

Table 1 shows the data on the subject's detection time for the supercritical events. The results indicate that the four symbology sets used in the experiment had no significance between or within subject effects.

The analysis of variance for the detection times of the critical events depicted statistical significance at the $\alpha=0.01$ level for within subjects but non-significance for between subject effects.

An additional post ANOVA test for significant difference between means was performed. Table 3 shows that a significant difference was found between the square and polygon and the square and triangle. No other combination of symbols had significant differences in their mean detection times for the critical events.

Composite scores were also determined for each symbology set. These scores were the sum of the four subtasks of the recognition task for all twenty subjects.

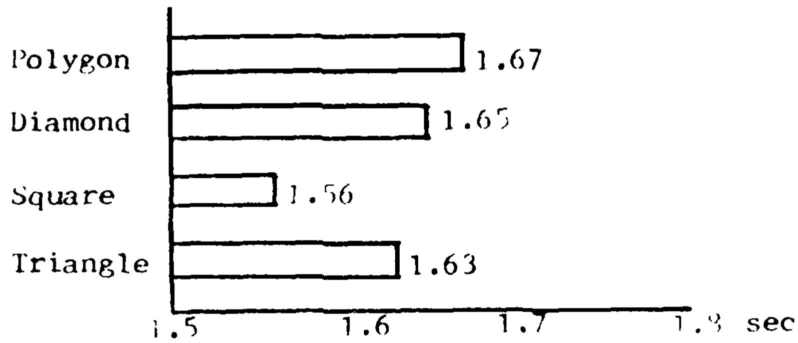

Figure 3. Mean detection times (Supercritical events).

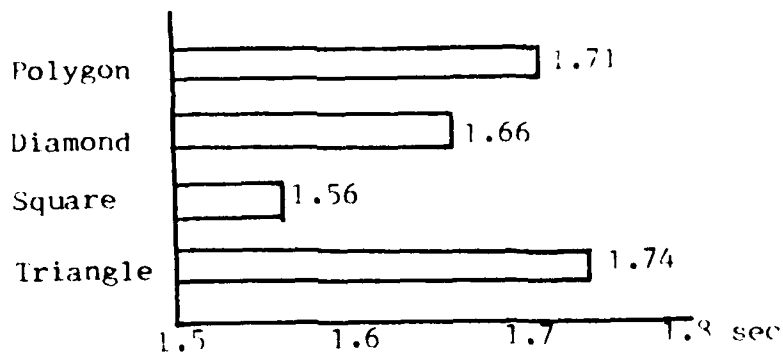

Figure 4. Mean detection times (Critical events).

TABLE 1

ANOVA for Performance of Detection Times (Supercritical Events)

Source	df	SS	MS	F
Between Subjects				
A (Symbology Sets)	3	0.14	0.05	0.55
Error	76	6.89	0.09	
Within Subjects				
A	3	0.14	0.05	1.74
B (Subjects)	19	5.25		
AB	57	1.64	0.03	
TOTAL	79	7.03		

(Source for analysis is Hicks, 1973)

TABLE 2

ANOVA for Performance of Detection Times (Critical Events)

Source	df	SS	MS	F
Between Subjects				
A	3	0.38	0.13	1.17
Error	76	8.27	0.11	
Within Subjects				
A	3	0.38	0.13	4.07**
B	19	6.49		
AB	57	1.78	0.03	
TOTAL	79	8.65		

** $p < 0.01$

TABLE 3

Newman-Keuls Procedure for Test on Means for Critical Event Detection Times

Ordered Means	Square	Diamond	Polygon	Triangle
	1.56	1.66	1.71	1.74
Differences Between Means				
Square		0.10	0.15	0.18
Diamond			0.05	0.08
Polygon				0.03
Test of Differences		--	*	*
			--	--
				--

$*p < 0.05$

The maximum possible score per subject was 235.

Prior to the analysis of variance on the composite scores, the mean composite scores were graphed as shown in Figure 5. As depicted, the diamond, although not the most easily detected, was in the forefront as the highest scoring symbol, while the square was last in overall performance. The analysis of variance data is summarized in Table 4. The F statistic indicates the differences between symbology sets were not significant at the 0.05 level. Also, within-subjects differences were not significant.

Of the total composite score for each symbol, there was a maximum of 141 points that could be awarded for correct symbol identification. From this view point, the triangle had a slightly higher mean symbol recognition score while the square was last. Figure 5 shows the portion of the composite score attributed to symbol recognition.

The composite score was also analyzed in terms of supercritical and critical events. Figure 6 shows that for supercritical events the diamond had the largest score as it had when the supercritical and critical data was combined. However, the polygon was last behind the triangle and square.

Figure 7 depicts the composite scores for the critical event data. Surprisingly, the polygon had the largest score while the diamond was second, and the square and

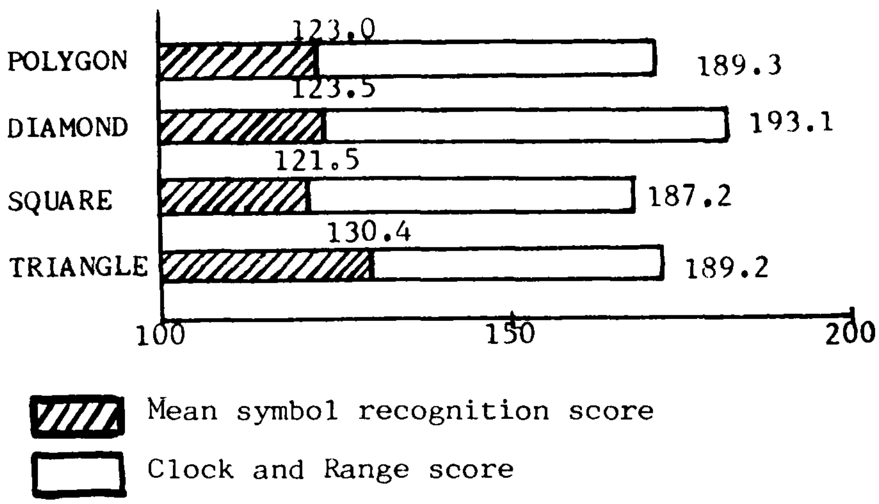

Figure 5. Mean performance scores (Composite scores).

TABLE 4

ANOVA for Performance (Composite Scores)

Source	df	SS	MS	F
Between Subjects				
A (Symbology Sets)	3	360.75	120.25	0.36
Error	76	25399.47	334.20	
Within Subjects				
A	3	360.75	120.25	0.61
B (Subjects)	19	14211.03		
AB	57	11188.44	196.29	
TOTAL	79	25760.22		

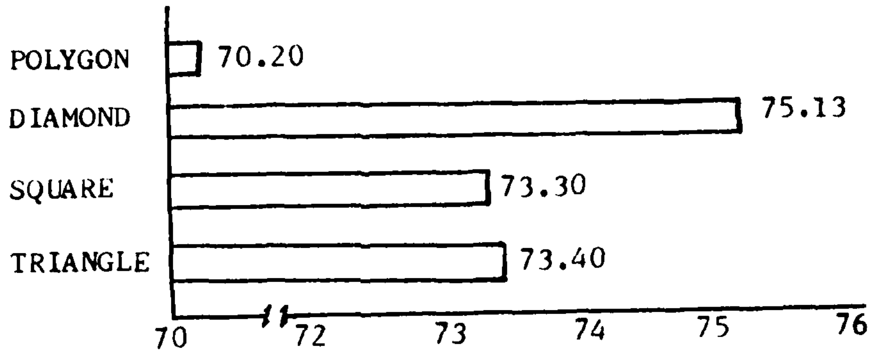

Figure 6. Mean performance scores (Supercritical events).

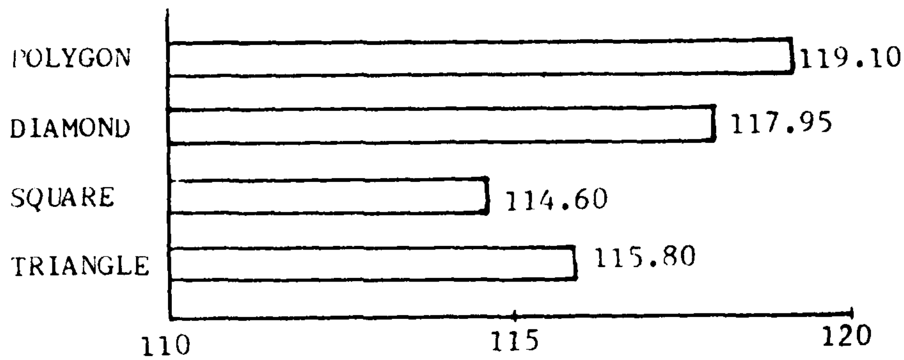

Figure 7. Mean performance scores (Critical events).

triangle were third and fourth in rank order.

To determine statistical significance, analysis of variance was performed on both the supercritical and critical event performance scores. Tables 5 and 6 summarize these results. Neither analysis of variance revealed statistical significance at the 0.05 level but the supercritical events showed significance at the 0.25 level.

Figure 8 shows mean performance scores on the compensatory tracking task. High scores on the task imply that the subject was less distracted by the particular symbology set. Hence, tracking with the polygon set appears to be <u>least</u> demanding while the diamond appears to be <u>most</u> demanding.

To determine if the symbology sets differed significantly, an analysis of variance was performed on the tracking task performance scores. Table 7 summarizes the effect of the symbology sets on the tracking task. As indicated, there was no statistical significance nor evidence that any of the symbology sets adversely affected the performance of the task.

TABLE 5

ANOVA for Performance (Supercritical Events)

Source	df	SS	MS	F
Between Subjects				
A	3	253.86	84.62	1.65 *
Error	76	3897.36	51.28	
Within Subjects				
A	3	253.86	84.62	2.31 *
B	19	1807.53		
AB	57	2089.83	36.66	
TOTAL	79	4151.22		

* $p < 0.25$

(For ease of computation an arbritary figure of 70 was subtracted from each score prior to analysis.)

TABLE 6

ANOVA for Performance (Critical Events)

Source	df	SS	MS	F
Between Subjects				
A	3	244.30	81.43	0.46
Error	76	13208.90	173.80	
Within Subjects				
A	3	244.30	81.43	0.82
B	19	7555.95		
AB	57	5652.95	99.17	
TOTAL	79	13453.20		

(For ease of computation an arbitrary figure of 100 was subtracted from each score prior to analysis.)

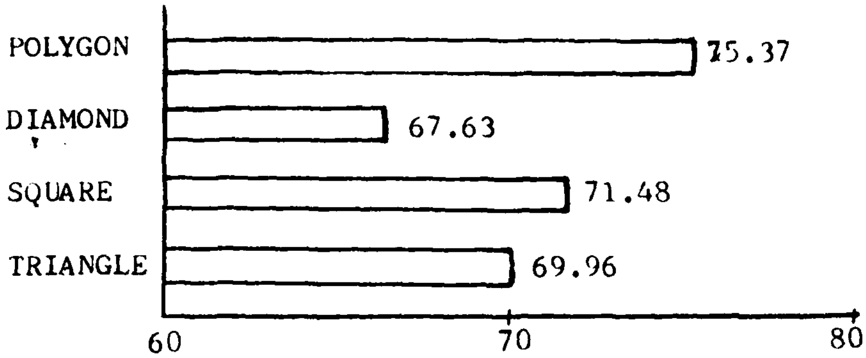

Figure 8. Mean performance scores (Tracking task).

TABLE 7

ANOVA for Performance (Tracking Task)

Source	df	SS	MS	F
Between Subjects				
A	3	653.00	217.70	0.42
Error	76	39794.00	523.60	
Within Subjects				
A	3	653.00	217.70	2.28
B	19	34354.00		
AB	57	5440.00	95.40	
TOTAL	79	40447.00		

(For ease of computation an arbitrary figure of 70 was subtracted from each score prior to analysis.)

CONCLUSIONS AND RECOMMENDATIONS

The hypothesis that a particular symbology set would result in significantly better performance was not supported.

The type of geometry of the symbol did not affect either mean detection time or mean performance scores for either supercritical or critical events.

Overall performance scores were not affected by the symbology sets used.

Compensatory tracking scores were not affected by symbology sets used.

Major contributer to composite score error was in range and direction estimation.

A possible explanation for the negative findings was that the recognition task was neither as difficult nor as complex as anticipated. It became a two-step binary decision, that is:

Is the symbol present? Yes/No?

If yes, is it supercritical or critical?

Unlike a search task, the array of symbols displayed at any given time were homogeneous in shape. For the purpose of detection, symbology was irrelevant. The primary task involved discriminating the detail which distinguished the two classes of events. Therefore, these findings should not be taken as evidence that type of symbology is not a variable except for the conditions studied in this experiment.

Recommendations for future research include:

Reporting the symbol by its characteristic shape in addition to its priority. This approach may result in more significant findings.

A physiological measurement may present stress information that could result in levels of performance being documented.

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APPENDIX A

ORDER OF PRESENTATION

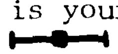
GROUP	TREATMENT			
I	A	B	C	D
II	D	A	B	C
III	C	D	A	B
IV	B	C	D	A

INSTRUCTIONS TO SUBJECTS

The purpose of the experiment was explained to the subject when he was seated at the console prior to testing:

> "The purpose of this study is to determine the effects of geometry on symbology recognition. The task will require your attention for detail and may be difficult. Do the best you can during the entire time of the experiment and do not stop until the tracking task automatically ends the experiment.
>
> Before you are a video monitor screen and a microcomputer with its attached video screen. The video monitor will present the tracking task while the computer screen will present the recognition task. You will now practice the tracking task."

Instructions for the tracking task was then read from the video monitor aloud to the subject.

> "This is your primary mission. You will center the  as closely as possible. It it is below you, pull back on the stick to climb. If it is above you, push forward on the stick to dive. If it is either to the right or left of you push the stick in that direction to correct. You will be scored on how well you do. Good Luck! To start the task, pull back on the stick."

The subject was then allowed to practice the tracking task for two 100 second intervals.

Practice of the Recognition task began after these instructions:

> "The computer console located directly in front of you will be displaying the symbology that you will respond to by hitting the correct key.
>
> The symbology sets to be tested are the polygon, diamond, square, and triangle.

The figure with the dot inside is the highest priority symbol and is called a supercritical event. You should respond to this symbol first and report the information in this sequence:

1. Hit the correct key,

2. Verbally respond by

   a. State priority

   b. Give Clock Direction

   c. Give Range

You will notice the diamond is entirely filled in. It is a representation of a supercritical event and report it as such.

The figures without a dot or just the outline are the next highest priority symbols. You will respond to these symbols after all the supercritical symbols have been responded to. You are asked to respond in the same manner as before, that is,

1. Hit the correct key,

2. Verbally respond by

   a. State priority

   b. Give Clock Direction

   c. Give Range."

The subject was then allowed to practice for a period of approximately 100 seconds for a practice sequence. This was repeated twice.

During the practice trials each subject received aid from the experimenter as to correct responses to the recognition task.

After the practice trials, the two tasks were combined

and each subject had two trials of 100 seconds each.

Final instructions were given to each subject as follows:

> "The first symbology set to be tested will be the ________. You will respond as previously instructed.
>
> Remember your primary mission is to track the  to the center of the screen and then respond to the recognition task.
>
> Are you ready? If so, please start the experiment by activating the joystick and pressing the space bar."

After each test these instructions were repeated for each symbology set.

> "The next symbology set to be tested will be the ________. You will respond as previously instructed.
>
> Again remember that your primary mission is tracking."

APPENDIX B

DETECTION TIMES
(SUPERCRITICAL EVENTS)

SUBJECT	POLYGON	DIAMOND	SQUARE	TRIANGLE
1	2.13	2.04	1.91	1.93
2	1.85	1.61	1.60	1.81
3	1.60	1.57	1.44	1.43
4	1.45	1.55	1.53	1.48
5	1.40	1.60	1.83	1.48
6	1.54	1.45	1.36	1.34
7	1.39	1.41	1.30	1.45
8	1.18	1.45	1.27	1.49
9	2.45	2.41	2.02	2.20
10	1.58	1.91	1.96	1.80
11	1.78	1.54	1.22	2.01
12	1.99	1.77	1.51	1.51
13	1.67	1.20	1.15	1.24
14	2.01	1.68	1.81	1.93
15	1.41	1.41	1.01	1.55
16	1.41	1.61	1.47	1.57
17	1.80	1.49	1.47	1.46
18	1.21	1.23	1.35	1.37
19	1.84	1.93	(1.91)	1.97
20	1.73	2.14	1.99	1.54

( ) signifies average value substituted for actual score due to subject not being administered this test symbology.

DETECTION TIMES
(CRITICAL EVENTS)

SUBJECT	POLYGON	DIAMOND	SQUARE	TRIANGLE
1	2.59	2.18	2.15	2.41
2	1.78	1.61	1.58	1.77
3	1.52	1.73	1.62	1.66
4	1.68	1.64	1.67	1.90
5	1.85	1.76	1.59	1.53
6	1.41	1.65	1.51	1.47
7	1.46	1.63	1.47	1.51
8	1.48	1.44	1.41	1.63
9	2.42	2.55	1.71	2.78
10	2.12	1.92	2.15	1.95
11	1.73	1.56	1.14	2.14
12	1.96	1.55	1.53	1.44
13	1.48	1.77	1.54	1.50
14	1.87	1.72	1.62	1.90
15	1.20	1.03	1.07	1.54
16	1.43	1.62	1.40	1.51
17	1.50	1.24	1.22	1.30
18	1.35	1.27	1.48	1.54
19	1.74	1.89	(1.78)	1.70
20	1.62	1.39	1.53	1.62

(   ) See page 1 of Appendix B

COMPOSITE SCORES

SUBJECT	POLYGON	DIAMOND	SQUARE	TRIANGLE
1	188.5	187.0	195.5	192.0
2	190.0	199.0	197.5	199.5
3	191.5	172.5	135.0	176.5
4	207.0	194.0	209.0	190.0
5	200.0	193.5	198.5	201.5
6	203.5	203.0	219.0	205.5
7	198.0	200.0	196.5	204.0
8	202.5	216.0	211.0	204.0
9	174.0	204.5	128.5	192.5
10	187.5	163.5	177.5	198.5
11	165.0	197.0	200.5	174.0
12	186.5	201.0	208.0	207.0
13	204.5	204.5	181.0	185.0
14	183.5	206.5	192.5	185.5
15	178.0	194.5	174.0	135.0
16	195.0	178.0	184.5	180.0
17	158.5	159.0	164.0	181.5
18	202.0	190.0	196.5	196.0
19	207.0	210.0	(208.0)	206.0
20	161.5	188.0	168.0	169.5

(   ) See page 1 of Appendix B

PERFORMANCE SCORES
(SUPERCRITICAL EVENTS)

SUBJECTS	POLYGON	DIAMOND	SQUARE	TRIANGLE
1	74.5	77.5	76.5	75.5
2	69.0	77.5	77.5	75.5
3	70.5	72.5	55.5	76.5
4	75.5	77.0	74.5	76.0
5	75.0	78.0	71.0	76.0
6	77.0	77.0	78.5	76.5
7	77.0	76.5	77.5	81.0
8	77.5	78.0	77.0	75.0
9	62.5	73.0	74.5	72.0
10	73.0	63.5	73.0	78.5
11	51.5	75.0	77.0	69.5
12	65.5	75.5	76.5	74.0
13	77.5	76.5	75.5	78.0
14	62.0	78.0	71.5	74.5
15	73.0	78.0	73.5	44.0
16	77.5	74.0	78.5	75.5
17	63.5	64.5	70.0	73.5
18	75.5	78.0	76.0	76.0
19	78.0	79.5	(78.5)	78.0
20	49.0	73.0	53.0	63.0

( ) See page 1 of Appendix B

PERFORMANCE SCORES
(CRITICAL EVENTS)

SUBJECTS	POLYGON	DIAMOND	SQUARE	TRIANGLE
1	114.0	109.5	119.0	117.0
2	121.0	121.5	120.0	124.0
3	121.5	100.0	79.5	100.0
4	131.5	117.0	134.5	114.0
5	125.0	115.5	127.5	125.5
6	126.5	126.0	140.5	129.0
7	121.0	123.5	119.0	123.0
8	125.0	138.0	134.0	128.0
9	111.5	131.5	67.0	120.5
10	114.5	100.0	104.5	120.0
11	114.5	122.0	123.5	104.5
12	121.0	125.5	131.5	133.0
13	127.0	128.0	105.5	107.0
14	121.5	128.5	121.0	111.0
15	105.0	116.5	100.5	91.0
16	117.5	104.0	106.0	104.5
17	95.0	94.5	94.0	108.5
18	126.5	112.0	120.5	120.0
19	129.0	130.5	(129.0)	128.0
20	112.5	115.0	115.0	107.5

(   ) See page 1 of Appendix B

PERFORMANCE SCORES
(PILOT RATINGS)

SUBJECTS	POLYGON	DIAMOND	SQUARE	TRIANGLE
1	72.77	86.89	69.14	66.33
2	91.00	67.04	56.95	56.95
3	67.54	40.88	59.92	67.91
4	58.59	45.05	56.61	61.28
5	59.89	53.44	72.41	66.80
6	74.42	48.31	69.11	57.44
7	100.84	80.65	68.80	72.41
8	124.63	112.52	118.84	105.16
9	66.57	75.26	58.52	69.91
10	99.97	72.98	82.55	98.13
11	65.28	59.26	69.51	50.10
12	30.02	28.46	39.13	27.35
13	99.97	106.06	116.08	114.30
14	85.28	78.43	93.13	79.26
15	33.82	40.05	48.76	34.04
16	91.45	77.88	98.13	74.49
17	41.83	37.75	51.40	46.33
18	91.73	91.13	72.36	110.29
19	76.20	73.97	(68.83)	54.81
20	75.70	76.64	58.96	77.71

( ) See page 1 of Appendix B

APPENDIX C

EXPERIMENTAL SYMBOLOGY PROGRAM

```
5 ID=19:TD=600
6 X$="":Y$=""
10 DIM C$(19),ET%(63,4),DT%(63,4)
12 C$(0)=""
14 C$(3)=",;%$$''<>%##"
16 C$(4)="  %$$''  %##"
18 C$(6)="@'%N#MM$N"
20 C$(5)=" '%N#MM$N"
22 C$(1)="@%NN%##"
24 C$(2)=" %NN%##"
26 C$(7)="NMMN"
28 C$(8)=")←←)"
30 C$(9)="%@':#LP$O"
32 C$(10)="% ':#LP$O"
34 C$(11)="1"
36 C$(12)="2"
38 C$(13)="3"
40 C$(14)="4"
42 C$(15)="5"
44 C$(16)="6"
46 C$(17)="7"
48 C$(18)="8"
50 C$(19)="9"
60 PRINT"HELLO.  WE ARE GOING TO PLAY A LITTLE":PRINT
65 PRINT"GAME TO KEEP YOUR MIND OFF THE OTHER":PRINT
70 PRINT"SCREEN.  EVERY SO OFTEN I WILL FLASH":PRINT
75 PRINT" ONE OR MORE OF THESE SYMBOLS FOR YOU:":PRINT:PRINT
80 FOR I=1 TO 10:PRINT" ";C$(I);:NEXTI:PRINT:PRINT:PRINT
85 PRINT"YOU RESPOND BY HITTING THE CORRECT KEY ":PRINT
90 PRINT"AND REPORTING VERBALY THE TYPE, RANGE,":PRINT
92 PRINT"AND BEARING OF THE HIGHEST PRIORITY":PRINT
94 PRINT"TARGETS.  PRESS THE SPACE BAR TO START":POKE 59459,0
96 GET A$:IF A$<>" " GOTO96
```

```
100 IT=0
110 FOR I=0 TO 1D: FL=0: F1=0: READ J1
112 PRINT "";
115 POKE 59409,52: RT=T1+900+4300*((RND(1)-.5)↑3): FOR J=0TOJ1-1
120 READ D,A,SY: AP=*A/6
130 X=INT(11.5+D*SIN(AP)/2.4)+9: Y=12.5-COS(AP)*D/3
160 PRINT LEFT$(X$,X);
170 PRINT LEFT$(Y$,Y);
180 PRINT C$(SY);"";IT=IT+1: NEXTJ
190 IF T1<RT GOTO190
200 PT=T1+TD
210 POKE 525,0
220 POKE 59409,60
225 A=PEEK(59471): B1=AANDB1: B2=AANDB2: IFA=255THEN 233
226 IF B1=B3 THEN230
227 IF FL<4ANDB1=0THEN ET%(1,FL)=T1-RT+TD: FL=FL+1
230 IFB2=B4THEN 233
232 IF F1<4AND B2=0THEN ET%(1,F1)=T1-RT+TD: F1=F1+1
233 B3=B1: B4=B2
240 IF T1<PT THEN 225
270 NEXT I
280 PRINT"END OF TEST."
301 FOR J=0TO3
302 GET A$:IF A$<>CHR$(13) THEN 302
303 PRINT "        SUPER CRITICAL TIMES("J+1;")"
305 PRINT " I"; TAB(5); "TIM"; TAB(10);" I"; TAB(15); "TIM"; TAB(20);" I";
306 PRINTTAB(25);"TIM"; TAB(30);" I"; TAB(35); "TIM"
310 FOR I=0 TO 15
320 PRINT I; TAB(5); ET%(I,J); TAB(10);I+16; TAB(15); ET%(I+16,J); TAB(20);
330 PRINT I+32; TAB(25); ET%(I+32,J); TAB(30);I+48; TAB(35) ET%(I+48,J)
345 NEXT I:NEXT J
346 FOR J=0TO3
348 GET A$:IF A$<>CHR$(13) GOTO348
350 PRINT "            CRITICAL TIMES("J+1;")"
```

```
360 PRINT " I";TAB(5);"TIM";TAB(10);" I";TAB(15);"TIM";TAB(20);" I";
370 PRINTTAB(25);"TIM";TAB(30);" I";TAB(35);"TIM"
380 FOR I=0 TO 15
390 PRINT I;TAB(5);ET%(I,J);TAB(10);I+16;TAB(15);ET%(I+16,J);TAB(20);
400 PRINT I+32;TAB(25);ET%(I+32,J);TAB(30);I+43;TAB(35)ET%(I+48,J)
410 NEXT I:NEXT J
420 END
1000 DATA 7, 9,1,11, 13,5,12, 13,11,5, 25,3,6, 22,6,5, 23,2,6
1010 DATA 2,11,17,2, 14,8,11, 30,6,12
1020 DATA 2, 12,7,5, 10,4,5
1030 DATA 7, 16,1,5, 8,4,6, 19,4,5, 15,2,6, 10,11,15, 16,12,16
1040 DATA 14,11,17, 3,2,6,5, 3,11,5, 7,4,5
1060 DATA 6, 11,3,6, 26,2,6, 22,12,11, 21,10,12, 16,5,13, 9,3,14
1070 DATA 8, 17,9,6, 13,4,6, 22,10,11, 12,12,12, 10,12,13, 17,4,14
1071 DATA 4,7,15,23,9,16
1080 DATA 4, 24,3,5, 10,9,5, 3,12,11
1081 DATA 29,12,12
1090 DATA 6, 13,9,11, 19,1,12, 27,3,13,13,11,14, 10,6,15, 19,5,16
1100 DATA 3, 29,7,11, 3,12,12, 27,7,13
1110 DATA 4, 14,11,5, 3,9,5, 1,4,11, 7,1,12
1130 DATA 5, 28,5,5, 15,12,5, 11,8,11, 11,2,12, 29,3,13
1160 DATA 1, 11,11,11
1170 DATA 5, 6,11,11, 4,3,12, 24,9,13, 4,12,14, 19,9,15
1190 DATA 5, 7,7,5, 17,7,5, 8,1,5, 12,12,5, 3,3,11
1200 DATA 3, 2,7,11, 16,4,12, 9,8,13
1210 DATA 3, 28,1,11, 30,9,12, 6,5,13
1230 DATA 8, 21,12,11, 20,1,12, 24,6,13,18,8,14, 12,4,15, 5,4,16
1231 DATA 27,12,17, 25,1,18
1240 DATA 9, 21,5,6, 21,12,6, 25,9,6
1241 DATA 24,7,11, 26,12,12, 13,3,13
1242 DATA 4,4,14, 14,4,15, 20,10,16
1260 DATA 6, 22,12,6, 10,8,11, 3,4,12
1261 DATA 14,12,13, 12,1,14, 29,5,15
1270 DATA 5, 8,1,11, 12,9,12, 10,3,13
```

```
1271 DATA 20, 1, 14, 2, 7, 15
1290 DATA 3, 18, 10, 5, 25, 12, 5, 29, 2, 5
1300 DATA 1, 12, 4, 11
1310 DATA 4, 3, 4, 11, 13, 11, 12, 5, 5, 13, 14, 4, 14
1320 DATA 4, 23, 4, 11, 27, 2, 12, 25, 2, 13, 16, 2, 14
1330 DATA 9, 17, 6, 5, 23, 3, 5, 25, 1, 5
1331 DATA 3, 2, 5, 15, 4, 6, 13, 7, 6, 23, 4, 11
1332 DATA 20, 10, 12, 21, 11, 10
1340 DATA 5, 27, 3, 5, 29, 12, 5, 27, 7, 11
1341 DATA 20, 7, 10, 28, 4, 13
1350 DATA 1, 14, 4, 11
1360 DATA 4, 2, 11, 11, 16, 5, 12, 11, 4, 13, 9, 11, 14
1370 DATA 6, 22, 5, 5, 4, 7, 11, 10, 6, 12, 4, 4, 13, 2, 3, 14, 14, 9, 15
1380 DATA 9, 13, 2, 5, 10, 12, 11, 4, 4, 12
1381 DATA 20, 1, 13, 10, 6, 14, 6, 6, 15
1382 DATA 7, 2, 16, 7, 1, 17, 3, 5, 18
1390 DATA 4, 3, 3, 3, 6, 11, 11, 22, 1, 12, 13, 1, 13
1410 DATA 1, 12, 4, 11
1420 DATA 1, 0, 0, 0
1430 DATA 9, 3, 10, 6, 23, 3, 6, 23, 4, 6, 13, 12, 11, 14, 10, 12, 12, 2, 13
1431 DATA 11, 7, 14, 6, 4, 15, 3.3, 4, 16
1440 DATA 1, 4, 10, 11
READY.
```

END OF PROGRAM

EXPERIMENTAL
TRACKING TASK PROGRAM

```
5 GOSUB 2000
8 DIMS(4):DATA118,54,81,54,117:FORI=0TO4:READS(I):NEXT
9 PRINT"":A=11:L=32768:DEFFNR(X)=INT(RND(1)*(X+1))
10 PRINTTAB(A);"       @@[@@
15 PRINTTAB(A);"         ]
20 PRINTTAB(A);"         ]
25 PRINTTAB(A);"        @[@
30 PRINTTAB(A);"         ]
35 PRINTTAB(A);"         ]
40 PRINTTAB(A);"]        [         ]
45 PRINTTAB(A);"]   ]          ]   ]
50 PRINTTAB(A);"[@@[@@[     [@@[@@[
55 PRINTTAB(A);"]   ]          ]   ]
60 PRINTTAB(A);"]        [         ]
65 PRINTTAB(A);"         ]
70 PRINTTAB(A);"         ]
75 PRINTTAB(A);"        @[@
80 PRINTTAB(A);"         ]
85 PRINTTAB(A);"         ]
90 PRINTTAB(A);"       @@[@@
91 PRINT"MISSION TIME =";TAB(27);"POINTS = 0"
92 DIMO(4):C=FNR(34):R=FNR(24):GOSUB500:FORI=0TO4:O(I)=PEEK(L+4+I):NEXT
94 TI$="000000":POKE 59459,0
```

```
100 REM**** MAIN LOOP ******
102 IF TI =>54000 GOTO900
105 B=PEEK(59471)AND15:CI=0:RI=0
115 IF(BAND8)=0THENCI=-2:GOTO125
120 IF(BAND2)=0THENCI=2
125 IF(BAND4)=0THENRI=-2:GOTO150
130 IF(BAND1)=0THENRI=2
150 REM**** MOVE SHIP ******
152 PRINT""TAB(14);"   ";INT(TI/60);TAB(35)"   ";XX
153 C=C+CI+FNR(2)-1:R=R+RI+FNR(2)-1
155 IFC<0THENC=0:GOTO165
160 IFC>34THENC=34
165 IFR<0THENR=0:GOTO172
170 IFR>24THENR=24
172 FORI=0TO4:POKEL+A+I,O(I):NEXT:GOSUB3500
175 FORI=0TO4:O(I)=PEEK(L+A+I):NEXT
180 FORI=0TO4:POKEL+A+I,S(I):NEXT
185 IF C=17ANDR=13THEN XX=XX+10
190 IF C>15ANDC<19ANDR>11ANDR<15 THEN XX=XX+5
200 YY=YY+1
285 GOTO100
```

```
500 REM**** ROW,COL TO ADDRESS ***
505 A=40*R+C:RETURN
900 REM**** EVALUATION  ******
905 T=TI
910 YY=YY*15
915 PRINT"*****  COMPUTER EVALUATION  *****"
920 PRINT"MISSION TIME (SEC)............";INT(T/60)
930 PRINT"TOTAL POINTS..................";XX
935 PRINT"PILOT RATING..................";INT(XX*10000/T)/100
940 END
2000 PRINT"     THIS IS YOUR PRIMARY MISSION."
2005 PRINT"YOU WILL CENTER THE *-0-4 AS CLOSELY"
2010 PRINT"AS POSSIBLE.  IF IT IS BELOW YOU,"
2020 PRINT"PULL BACK ON THE STICK TO DIVE. IF IT"
2030 PRINT"IS ABOVE YOU, PUSH FORWARD TO CLIMB."
2040 PRINT"IF IT IS TO YOUR RIGHT OR LEFT, PUSH"
2050 PRINT"THE STICK IN THAT DIRECTION TO CORRECT."
2060 PRINT"YOU WILL BE SCORED ON HOW WELL YOU DO."
2070 PRINT"              GOOD LUCK!"
2100 PRINT" TO START TASK, PULL BACK ON THE STICK"
2110 POKE 59459,0:XX=0:YY=0
2120 IF PEEK(59471)<>251   THEN 2120
2130 RETURN
READY.
```

END OF PROGRAM

VITA

JAMES ANDRUS BOYLESS

Born: April 21, 1945

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Educational Background:

Texas A&M University, College Station, Texas
Master of Science--Industrial Engineering, May 1979

Wright State University, Dayton, Ohio
Bachelor of Arts--Spanish, May 1977

University of Arizona, Tucson, Arizona
Bachelor of Science--Mechanical Engineering, May 1974

Taylor Center High School, Taylor, Michigan

Military Service:

Entered on Active Duty on April 22, 1965. Commissioned as Second Lieutanent September 10, 1974. Presently serving as Captain in the Regular component of the USAF.

The typist for this thesis was Mrs. Margaret L. Boyless

DATE
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